Development of STEM Education based Instructional Strategies and its Effect on Higher Order Thinking Skills and Academic Motivation of Secondary Stage Students

Synopsis

Submitted in the partial fulfilment for the requirement of

Doctor of Philosophy

In

Education

Submitted by

Asmita Sharma

Under the supervision of

Prof. Meenu Singh

Department of Pedagogical Sciences, Faculty of Education

Dayalbagh Educational Institute (Deemed to be University)

Dayalbagh, Agra- 282005

2023

1.0 INTRODUCTION

Education is an effort to empower people to become fully human beings so that they can actualize themselves, understand themselves and be able to support themselves. In education process, educators can be a facilitator that supports the process of achieving educational goals (Sudarsana, 2016).

Recent advancement in information and communication technology continue to affect the aspect of society, along with important implication in the field of education. Countries to be a leader in the scientific and technological race also attach great importance to science and mathematics education. For this reason, in order not to fall behind in the technological race, they have adopted the basic aim of raising individuals who understand science and mathematics conceptually well, associate these concepts with daily events, and can solve the problems they face in daily life with the information transferred in schools (Cepni, 2017).

National Research Council (NRC, 2007) reported that the strength of the nation is resulting in huge part from the point of view of production of skilled human beings and the stream of scientific and technical innovations they develop**. National Curriculum Framework for Teacher Education (NCFTE,2009)** reported that with the rise in science, social trends, advancement in technology and growth in research is a notch of education.

1.0.1 STEM (Science, Technology, Engineering and Mathematics) EDUCATION

William (2011) defines STEM education as an approach that supports participation using engineering and technology and improves students' learning in science and mathematics. STEM education is an approach that eliminates the boundaries between disciplines by enabling students to understand the world as a whole rather than parts (Lantz, 2009). According to Sahin et al. (2014), STEM education aims to enable individuals to look at problems from a different perspective between fields by gaining skills and knowledge with a totalitarian approach to education.

STEM term introduced by the **NSF (National Science Foundation), United States in 1990** as an abbreviation for **"Science, Technology, Engineering and Mathematics"** (Sanders, 2009). According to the United States Department of Education (2007), states that STEM education is an educational program with the study of science, technology, engineering and mathematics embedded in its core objectives, in order to strengthen the education. "S" for Science which is very much concerned with

what is the natural world and preparing students to think and act like a real scientist, ask questions, hypothesize, and conduct investigations using standard science practices (Kelley & Knowles, 2016). "T" for Technology which is the modification of natural world to meet human wants and needs. "E" for Engineering, stands as a profession in which knowledge of the mathematical and natural with judgement to improve ways to utilize the materials and forces of nature economically for the benefit of human being. "M" for Mathematics is defined as the science of patterns and relationship that provide the exact language for technology, science and engineering (Dugger, 2010).

Application of STEM approach in learning is of course integrated during the learning process. The four aspects of STEM take part in every implementation of the learning steps. The steps of each implementation are (1) the science aspect as the skill of using knowledge and science process in comprehending natural phenomenon and manipulating the phenomenon so that it can be implemented; (2) technology aspect as the skills of learners in knowing how new technologies can be developed, the skill of using technology, and how technology can be used in facilitating human work; (3) the engineering aspect as person's skill to operate or assemble something; and (4) mathematics aspect as a skill used to analyze, give reason, communicate ideas effectively, solve problems and interpret solutions.

1.0.2 HIGHER-ORDER THINKING SKILLS

Learning process is not enough to transfer information to remember and store it in the brain, but it needs education that helps students to have thinking skills (Subiantoro, 2017). Thinking skills refer to mental activities that allow individuals to make meanings for various information obtained to form relevant knowledge to solve problems (Subiantoro, 2017). Thinking skills encourage individuals to think creatively and critically in decision-making and problem-solving. Such thinking skills are known as higher-order thinking skills (HOTS).

The concept of Higher-order thinking skills is derived from Bloom's Taxonomy (1956). There are six orders of Bloom's Taxonomy, consist of memorizing, understanding, applying, analyzing, evaluating and creating (Afandi & Sajidan, 2017). Bloom's Taxonomy classified thinking skills into higher and lower-order thinking skills. Memorizing, understanding and applying as lower-order thinking skills and analyzing, evaluating and creating as higher-order thinking skills (Anderson et al., 2010). The cognitive process dimension has six levels and several indicators based on bloom's taxonomy, revised by

Anderson & Krathwohl (2001). The first level is remembering (C1), taking knowledge from long-term memory. The indicators of remembering are recognizing and recalling. The second level is understanding(C2), constructing meaning from learning the material, including what is said, written and drawn by the educator. The indicators are interpreting, modeling, classifying, summarizing or concluding, comparing and explaining. The third level is applying (C3), applying or using a procedure in certain circumstances. The indicators include executing and implementing. The fourth level is analyzing (C4), dividing the material into several parts and determining the relationship of each piece, between parts and the whole. The indicators are differentiating, organizing and attributing. The fifth level is evaluating (C5), making decisions based on standards or criteria such as checking and criticizing. The sixth level is creating (C6), which combines several parts to form something new and original. The indicators are formulating, planning and producing.

1.0.3 ACADEMIC MOTIVATION

Motivation is one of the most important sources of power that determines the direction, intensity and determination of student behavior in teaching-learning process. Motivation is both an attractive and hindering subject. It is interesting because it is behind almost everything a person does (Gottfried, 1990). Academic motivation is defined as the students' desire or interest in engaging with learning and their school experience (Hulleman, et al., 2016). Academic motivation can be defined as a form of cognitive and emotional arousal that influence a learner's academic achievement (Vallerand et al., 1992).

According to Hakan and Munire (2014), academic motivation is an internal state that activates, directs and maintains learning-related behaviors. Two main types of motivation, extrinsic and intrinsic motivation, lie as groundwork underpropping a large number of theories of motivation such as expectancy-value theory (Wigfield, Tonks, & Johnson, 2002). Learner's academic motivation is the result of interactions between classroom factors and the student's particular characteristics (Wigfield & Eccles, 2000).

1.1 EMERGENCE OF THE PROBLEM

Science and technology are inseparable parts of modern life. The development of science and technology can bring convenience and a new way of life, but on the other hand mastering science and technology is an important key to facing challenges in the future (Wahyu, et al. 2020). Society is needed to have

certain abilities in order to be able to complete and live properly in the rapid development of science and technology. In the field of work, a person must have skills in science and mathematics, creativity, mastery of information and communication technology, and be able to solve complex problems Murnawianto, et al. 2019).

NEP (1986) stated that the present curriculum is narrowly conceived, learning has become a rather mechanical process of acquiring skills and teaching has been largely a process of coaching for examination and testing the memory. Present syllabus is emphasizing more on memorization and recall of information. Little or no progress was made in training the pupils in practical side of science. **National Knowledge Commission (2006-09)** recommended that all school children should be encouraged to involve in some practical activities that require working with hands.

Studying the assessment system of India shows that students are expected to apply more memorization and less using higher order thinking skills, such as analysis, synthesis and evaluation. Thus, the students are mainly reliant on rote learning. This argument has been supported by many Indian educationists and researchers. For instance, speaking with the Times of India (June 19,2011), former chairman of UGC and the chairman of the **NCERT's National Curriculum Framework 2005**, Professor Yashpal told: "no one can get 100% in so many subjects. Clearly, we can see the emphasis on rote learning, and an exam-oriented approach, which is killing creativity and soft skills. This is conspiracy of examiners, school and coaching industry." Likewise, according to a research paper by NCERT official submitted to the International Association for Educational Assessment, the present system of assessment and evaluation for school education in India is exam-based. The research paper also states, "Assessment focuses only on cognitive learning outcomes and in the process, co-curricular domains are neglected, even though co-curricular areas are equally important and significant part of child development. Even in curricular areas, the focus is on rote learning and memorization, characterized by a neglect of higher mental abilities such as critical thinking, problem solving and creative ability" (Sahay,2015)

Dincer (2014) argues that the basic resources of the economy are individuals who can produce knowledge and use them when necessary. For this reason, it is important to educate the new generation with skills such as analytical, creative, and critical thinking, which are called 21st century skills. The way to gain these skills through STEM (Science, Technology, Engineering and Mathematics) which is

the basis of today and future science and technological development along with the holistic development of the students. The systematic convergence of science, technology, engineering and mathematics into an integrated STEM curriculum provides students a more extensive base of real-life learning skills (English & king, 2019; Fan et al., 2012). This convergence helps students learn STEM content through the application of scientific method and the cycle of engineering design (MacFarlane, 2015; Margot & Kettler, 2019; Self, 2020).

NEP, 2020 recommends to "encourage rational, logical, analytical and quantitative thinking in all aspects of the curriculum" (NEP,2020, p.88). It also recommends that assessments of educational approaches are to integrate the humanities and arts with Science, Technology, Engineering and Mathematics (STEM) have consistently showed positive learning outcome, including increase creativity and innovation, critical thinking and higher-order thinking capabilities, problem-solving abilities, teamwork, communication skills, more in-depth learning and mastery of curricula action fields, increase in social and moral awareness, etc. (NEP,2020, p 36).

There are so many approaches, methods, models and learning material in education that can make the students interested in learning science, one of them is STEM which is implement in the classrooms all around the world today by the educators. STEM itself is active learning that students centered integrated from one subject to other. STEM is also the innovative learning that leads to inquiry, project-based learning, and problem-solving (Breiner et al., 2012). STEM education is to motivate students as innovator, logical thinker, problem solver, technologically literate and using technology in their life and relationship with their own culture (Stohlman et al., 2012). Learning with STEM approaches promotes hands-on activity that is very important for students. Hands-on activities with contextual learning positively affect students' attitudes towards learning and content knowledge or cognition (Kaldi et al., 2011). The tremendous results show that students who studied and took STEM learning in the class showed positive attitude and achievement, success in courses and school (Dominguez & Jaime, 2010).

1.2 JUSTIFICATION OF THE PROBLEM

Science and technology are overgrowing. That is becoming a basic need for humans to gain daily information. Furthermore, now society is really engaged with gadget and demand higher digital technology. That causes the flow of information very easy to be received to be called a revolution

industry. In order to cope with the rapid developments in the information and technology age, individuals need to adopt to innovations. In order for individuals to adopt to innovations, it is of great importance to possess creativity, critical thinking, research, questioning, problem solving and collaboration skills, which are included among the 21st century skills (Morrison, 2006). STEM education would develop the 21st century skills in the individuals.

Some of the recent researches carried out in this field includes: Fatih Ozkan & Todd Kettler (2022) concluded that STEM education positively affects Gifted Students'Academic and Social-Emotional development. Fazilet Tasdemit (2022) observed the effect of STEM education showed the largest effect in Discipline of Science. Jolien De Meester, et al (2021) claims that the i-STEM design process resulting from this Study can fuel Teacher Training Programs and empower pre- and in-service Teachers to create high-quality Integrated STEM education. Dr. Ibrahim Yasar KAZU & Kurtoglu Yalcin (2021) observed the effect of STEM education showed the largest effect in Discipline of Science. Aristo Hardinata, Djulia Bukhari & AM Siregar (2021) revealed that how Teaching Material and Lesson Plans were developed on STEM and Scientific Literacy at the Plan Stage through Lesson Study. Tassaneewon Lertcharoenrit (2020) affirms that Students improved collaborative and problem-solving Competencies. Annisa Nurramadhani, Suci Siti Lathifah, & Irvan Permana (2020) made an attempt to know the Students' Generated Questions Quality by developing STEM-based E-Module in Science Learning and it was found that The Implementation of developed STEM-based E-Module is achievable and Students' Question Quality is improved. Ugar Sari, Esra Dunygu, Omer Faruk Sen & Talip Kirindi (2020) reported that STEM education performed in SBIL Environment has a positive effect on the development of Scientific Process Skills and STEM Awareness. Mustafa UGRAS (2018) observed that there was a significant difference between STEM Attitudes, Scientific Creativity and Motivation Beliefs of the Students.

On the basis of review of researches in the field of STEM education, the researcher has found that STEM education is helpful somehow to get academic success, social-emotional development, collaborative problem-solving competencies, scientific creativity and effective ways of communication etc. among students. The researcher has found that very few researches related to STEM education or instructional Strategies on STEM education have been conducted so far. Using traditional teaching methods would

not serve the purpose at large. Need has been felt to innovate or redesign the teaching programme by creating new type of material and techniques to develop Higher order thinking skills. Researcher also found that no study has been conducted to study the *Development of STEM education based Instructional Strategies and its effect on Higher-order thinking skills and Academic Motivation of Secondary Stage Students.* After analysis of previous researches, the questions raised in the researcher's mind are:

- Whether the limitations of Traditional teaching learning process can be improved by the STEM Education based Instructional Strategies?
- What will be the effect of developed STEM Education based Instructional Strategies on Higher-Order Thinking Skills of Secondary Stage Students?
- What will be the effect of developed STEM Education based Instructional Strategies on Academic Motivation of Secondary Stage Students?

1.3 STATEMENT OF THE PROBLEM

Viewing the facts available in explored researches the researcher has identified the problem stated as "Development of STEM Education based Instructional Strategies and its Effect on Higher-Order Thinking Skills and Academic Motivation of Secondary Stage Students".

1.4 DEFINITIONS OF THE TERMS TO BE USED IN THE STUDY

1.4.1 STEM Education

According to Tsupros (2009), "STEM education is an interdisciplinary approach to learning where rigorous academic concepts are coupled with real-world lessons as students apply science, technology, engineering, and mathematics in contexts that make connections between school, community, work, and the global enterprise enabling the development of STEM literacy".

Operational Definition

In the present study, STEM Education is an interdisciplinary approach of Science, Technology, Engineering and Mathematics. In which Science aspect will be included as a skill of using knowledge, Technology aspect as a skill of using technology, Engineering aspect as a students' skill to operate or assemble something and Mathematics aspect as a skill used to analyze, give reason, solve problems and

interpret solutions.

1.4.2 Higher-Order Thinking Skills

According to Zohar and Barzilai (2015), "Higher-order thinking skills include critical, logical, reflective, metacognitive, and creative thinking. They are activated when individuals encounter unfamiliar problems, uncertainties, questions, or dilemmas. Successful applications of the skills result in explanations, decisions, performances, and products that are valid within the context of available knowledge and experience and that promote continuous growth in these and other intellectual skills".

Operational Definition

In the present study, as per Anderson and Krathwohl (2001) Higher Order Thinking Skills are the skills of higher level abilities of mind rather than memorizing facts; which includes Analyzing, Evaluating and Creating.

1.4.3 Academic Motivation

According to Hulleman (2016), "Academic motivation is defined as the students' desire or interest in engaging with learning and their school experience."

Operational Definition

The definition given by Hulleman (2016) will be accepted as the operational definition for the present study.

1.4.4 Instructional Strategies

According to Dick & Carey (2005), "An Instructional strategy includes a sequence for teaching clusters of content, descriptions of learning components, specifications of how students will be grouped during instruction and selection of media for delivering instruction."

Operational Definition

In the present study, Instructional Strategies will be taken as the process of systematic sequencing and methods of instruction used in lessons to achieve learning objectives. These are the approaches that use in the design, development and delivery of content to engage learners in learning experiences.

1.4.5 Secondary Stage Students

According to NEP (2020), The Secondary Stage comprises of classes 9^{th} to 12^{th} (age group- 14 to 18 years).

Operational Definition

In the present study, Secondary Stage Students are the students of class IX, which covers students of age group 14-15 years.

1.5 OBJECTIVES OF THE STUDY

The Objectives of the present study are as follows:

1. To develop the STEM Education based lesson plans as Instructional Strategies for Secondary Stage Students.
2. To study the effect of STEM Education based Instructional Strategies on Higher-Order Thinking Skills of Secondary Stage Students.
    - To study the effect of STEM Education based Instructional Strategies on Analytical Skills.
    - To identify the effect of STEM Education based Instructional Strategies on Evaluative Skills.
    - To study the effect of STEM Education based Instructional Strategies on Creative Skills.
3. To study the effect of STEM Education based Instructional Strategies on Academic Motivation of Secondary Stage Students.

1.6 HYPOTHESES OF THE STUDY

In order to test the objectives of the study the following alternative hypotheses have been formulated:

Ha1: There will be a significant effect of STEM Education based Instructional Strategies on Higher-Order Thinking Skills of Secondary Stage Students.

Ha2: There will be a significant effect of STEM Education based Instructional Strategies on Academic Motivation of Secondary Stage Students.

1.7 DELIMITATIONS OF THE STUDY

The study will be limited to the following points:

- The study will be delimited to Secondary School of Agra city (Uttar Pradesh) only.
- The study will be delimited to UP Board only.

- The study will be conducted on class IX students.
- The study will be delimited to science subject only.

1.8 METHODOLOGY OF THE STUDY

1.8.1 VARIABLES OF THE STUDY

The variables related to the present study have been classified as:

Independent variable: STEM Education based Instructional Strategies

Dependent variables: Higher-Order Thinking Skills (HOTS) and Academic Motivation

Extraneous variables:

These variables will be controlled as shown in the following table:

Table 1: Control of Extraneous Variables

Category of variables	Extraneous Variables	Controlling techniques	Method of Control of Extraneous Variable
Subject related variables	Age SES	Sample Selection	Through Randomization
	Anxiety	Rapport Establishment	By Researcher
Environment related variables	Classroom Climate	Rapport Establishment	By Researcher
	Noise	Remove	Psychologically by Researcher
	Light Test time Test Administration	Constancy	By Researcher
Sequence related variables	Practice	Eliminated	Psychologically by Researcher
	Fatigue	Eliminated	Psychological by Researcher
	Cooperation	Constancy	By Researcher

1.8.2 METHOD OF THE STUDY

For the present study Quasi Experimental Research design will be used to test the effect of STEM Education based Instructional Strategies on Higher-Order Thinking Skills and Academic Motivation of Secondary Stage Students.

1.8.3 RESEARCH DESIGN

The research design will be Two Group Pre-Test Post-test. It is given in table 2

Table 2: Research Design of the Study

Groups	Pre-test	Treatment	No. of Lessons	Post-test
Control Group (N=40 Approx.)	Pre-test of Secondary Stage Student's Higher-Order Thinking Skills and Academic Motivation	Teaching of Science lessons using Traditional Method (3 months Approximately)	20 Lessons (Duration of each lesson 45 min Approx.)	Post-test of Secondary Stage Student's Higher-Order Thinking Skills and Academic Motivation
Experimental Group (N=40 Approx.)	Pre-test of Secondary Stage Student's Higher-Order Thinking Skills and Academic Motivation	Teaching of Science lessons using STEM education (3 months Approximately)	20 Lessons (Duration of each lesson 45 min Approx.)	Post-test of Secondary Stage Student's Higher-Order Thinking Skills and Academic Motivation

1.8.4 STEPS FOR DEVELOPING STEM EDUCATION BASED LESSON PLANS

The lesson plans based on STEM education will be developed by the researcher in following steps:

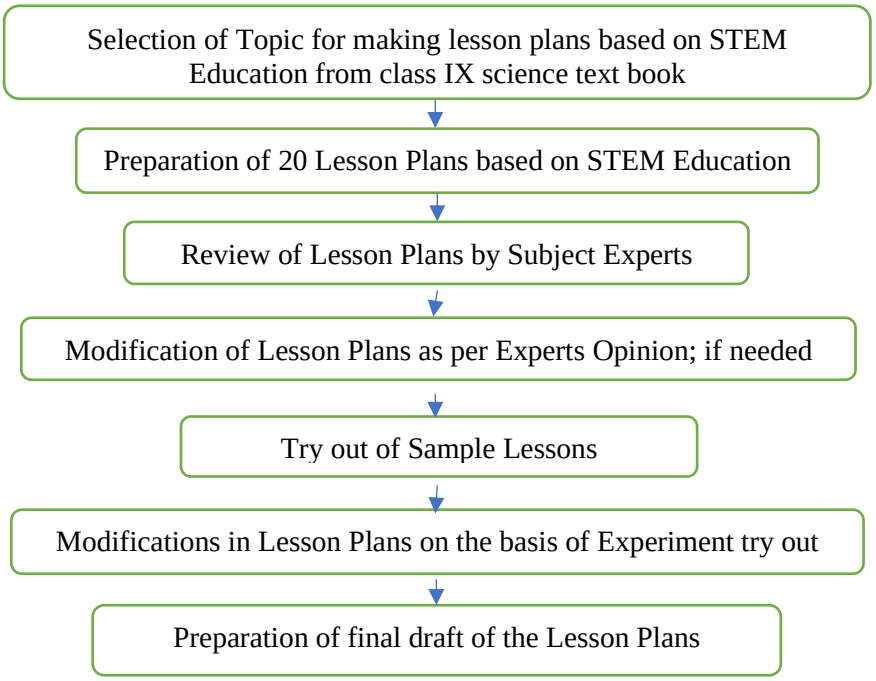
Selection of Topic for making lesson plans based on STEM Education from class IX science text book
Preparation of 20 Lesson Plans based on STEM Education
Review of Lesson Plans by Subject Experts
Modification of Lesson Plans as per Experts Opinion; if needed
Try out of Sample Lessons
Modifications in Lesson Plans on the basis of Experiment try out
Preparation of final draft of the Lesson Plans

Fig 1: Development of STEM Education based lesson plans

1.8.5 PREPARATION OF LESSON PLANS BASED ON STEM EDUCTAION

In the present study, the researcher will follow the procedure to develop the lesson plans based on STEM Education; given in table 3.

An example of lesson plan for the STEM activity to achieve learning outcomes.

Table 3: Sample Lesson Plan for IX Class Students

<table>
<tr><td colspan="3">Title of the lesson: Balanced and unbalanced forces

Objectives: • To develop ability to understand the concept of balanced and unbalanced forces.

• To develop the ability to identify the differences between balanced and unbalanced forces.
Teaching Learning Material Required: Related video, Scale, Eraser, Table, Water bottle cap, Stick Puppet etc.</td></tr>
<tr><th>PHASE</th><th>TEACHING LEEARNING ACTIVITY</th><th>NOTES</th></tr>
<tr><td>Preparation</td><td>1. Students will watch a video presented by the teacher related to things in real life with balanced and unbalanced forces.</td><td rowspan="3">S (Science): observe the moving objects and things in nature.

T(Technology): learn to use scale, water bottle cap etc.

E (Engineering): create a stick puppet with accurate measure of sticks to show the concept of balanced and unbalanced forces

M (Mathematics): create mind map and to categorize the balanced and unbalanced forces.</td></tr>
<tr><td>Presentation</td><td>1. Teacher will explain the concepts of balanced and unbalanced forces.
2. Students will conduct a demonstration with the help of teacher.</td></tr>
<tr><td>Practice</td><td>1. Students will make a stick puppet to show the concept of balanced and unbalanced forces.
2. Students will create a Mind map based on balanced and unbalanced forces.
3. Students categorize the balanced and unbalanced forces.</td></tr>
</table>

1.8.6 SAMPLE SELECTION

For the present study, the target population will be Secondary Stage Students (UP Board) of Agra city. Class IX students will be selected as a sample and number of sample units will be 80 approximately. One Experimental group and one Control group; 40 approx. in each group. Purposive Sampling will be used for selection of board and school. Intact Sampling will be assigned for selection of section of science as control and experimental (intact group). The sample selection process will be as follows:

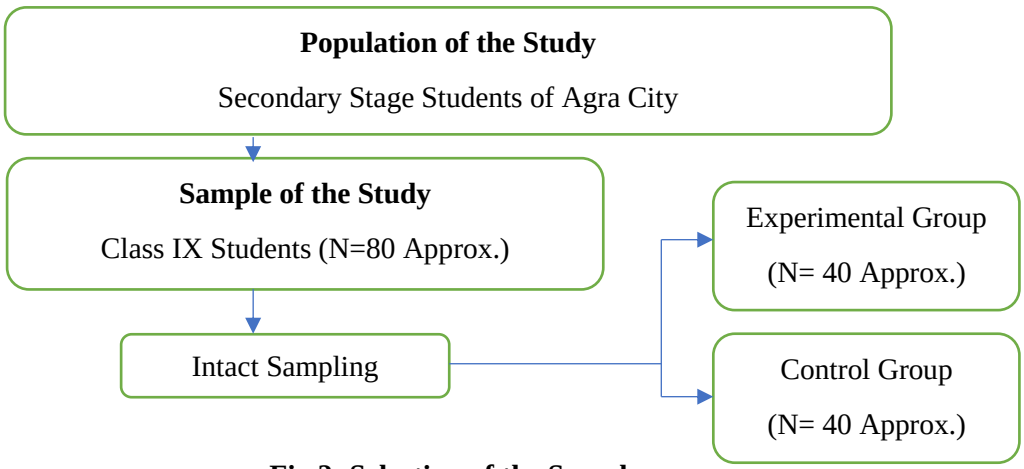

Fig 2: Selection of the Sample

1.8.7 TOOLS OF THE STUDY

In the present study, Pre-test and Post-test will be constructed for testing/ evaluating the achievement of science subject which will be taught using STEM education. Tools will be used are as follows:

- Self-Constructed tool for the measurement of Higher-Order Thinking Skill based on three dimensions of Higher Order Thinking Skills (HOTS); Analyzing, Evaluating and Creating.
- Academic Motivation Inventory constructed by Prof. K. S. Misra in 2020 [Reliability: Split half reliability (0.875), validity: face validity].

1.8.8 STATISTICAL TECHNIQUES

Descriptive Statistics: Mean, Standard deviation will be used to know the nature of data.

Inferential Statistics: Analysis of Co-Variance (ANCOVA) will be used for comparison between control and experimental group differences by controlling covariate effect.

Graphical Representation will be used for presenting data and results in visual form.

1.9 PROCEDURE OF THE STUDY

Procedure of the present study will be including the following steps:

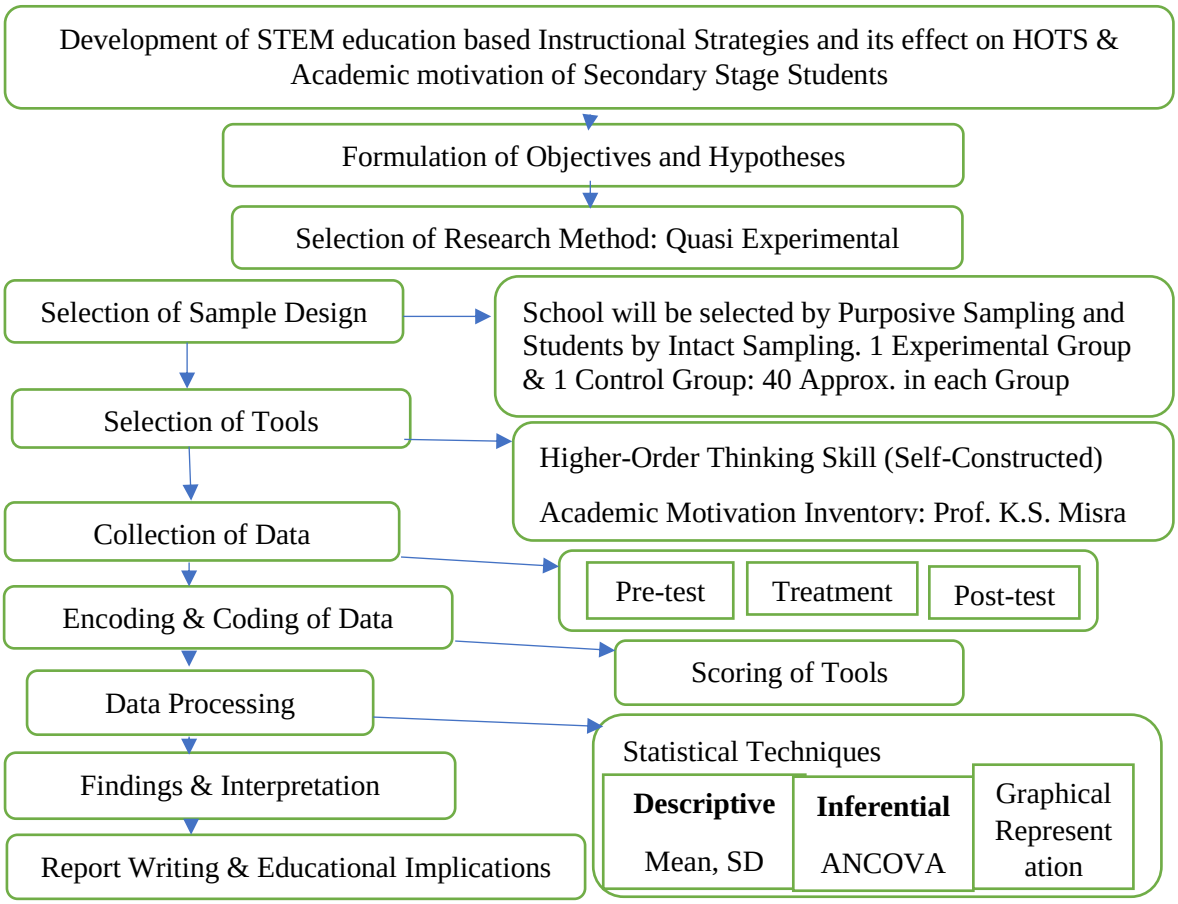
Development of STEM education based Instructional Strategies and its effect on HOTS & Academic motivation of Secondary Stage Students
Formulation of Objectives and Hypotheses
Selection of Research Method: Quasi Experimental
Selection of Sample Design
School will be selected by Purposive Sampling and Students by Intact Sampling. 1 Experimental Group & 1 Control Group: 40 Approx. in each Group
Selection of Tools
Higher-Order Thinking Skill (Self-Constructed)
Academic Motivation Inventory: Prof. K.S. Misra
Collection of Data
Pre-test
Treatment
Post-test
Encoding & Coding of Data
Scoring of Tools
Data Processing
Statistical Techniques
Descriptive
Mean, SD
Inferential
ANCOVA
Graphical Representation
Findings & Interpretation
Report Writing & Educational Implications

Fig 3: Research Procedure

1.10 SIGNIFICANCE OF THE STUDY

STEM Education refers to providing opportunities for students to become problem solver, innovators, self-confident, logical thinkers and technologically literate (Morrison,2006). Improving STEM education may also increase the literacy of all people across the population in technological and scientific areas (Pleasants et al., 2019).

The student is an active processor and interpreter of the classroom setting, so student's academic motivation can be enhanced by engaging students in meaningful learning activities (Gredler, 2001). Thus, classroom goal structures, teacher reactions to student performance, and individual differences should be carefully designed or examined in the educational setting (Gredler, 2001).

So. There is a need for appropriate learning method and strategies to enhance the learning outcome of the students. One of the teaching learning strategy is STEM Education. STEM Education provides teachers with a number of methods to engage students in an interdisciplinary way. By utilizing this method into classroom, the teacher meets the needs and learning strength of the students to make students academically stronger.

This research will be helpful to administrators, educationist, parents, teacher and also for students. This research will also provide an idea to implement flexible teaching methods and strategies according to the needs of the students. The present study can also be seen as effort if STEM education is found useful in education in the direction of transformation in the teaching methodology from teaching using traditional methods towards teachers using STEM Education to enhance Higher-Order Thinking Skills and academic motivation.

Thus, the study undertaken by the researcher is expected to prove the positive effect of STEM Education based instructional Strategies on Higher-order thinking skills and Academic motivation of Secondary Stage Students.

REFERENCES

Afandi, & Sjidan. (2017), *Stimulasi Keterampilan Berpikir Kritis.* Surakarta: UNS Press.

Anderson, L.W., Krathwohl, D.R., & Bloom, B.S. (2001). *A taxonomy for learning, teaching and assessing: A revision of Bloom's taxonomy of educational objectives (Abridged ed.).* New York: Longman.

Bloom, B.S. (1956). *Taxonomy of Educational Objectives: The Classification of Educational Goals Handbook Cognitive Domain.* London: Longmans Inc.

Breiner, J. M., Harkness, S.S., Johnson, C.C., & Koehler, C.M. (2012). What is STEM? A discussion about conceptions of STEM in education and partnerships. *School Science and Mathematics, 112*(1), 3-11.

Cepni, S. (2017). *STEM education from practice to theory*. Ankara: Pegem Publishing.

Dick, W., Carey, L., & Carey, J.O.(2005). *The Systematic Design of Instruction.* Boston, Massachusetts: Pearson/Allyn and Bacon

Dincer, S. (2014). STEM education, and labor force. *Journal of TUSIAD*, 85, 10-11.

Dominguez, C., & Jaime, A. (2010). Database design learning: A project-based approach organized through a course management system. *Computers & Education, 55*(3), 1312-1320.

Dugger, W.E. (2010). Evaluation of STEM in the United States. Paper presented at the 6th Biennial International conference in Technology Education Research'nda sunulmus bildiri, Gold Coast, Queensland, Australia.

English, L,D., & King, D. (2019). STEM integration in sixth grade: design and constructing paper bridges. *International Journal of Science and Mathematics Education, 17*(5), 863-884. https://www.doi.org/10.1007/s10763-018-9912-0

Fan, S. C., Yu, K.C., & Lin, K. Y. (2021). A framework for implementing an engineering-focused STEM curriculum. *International Journal of Science and Mathematics Education, 19*, 1523-1541. https://www.doi.org/10.1007/s10763-020-10129-y

Gottfried, A.E. (1990). Academic intrinsic motivation in young elementary school children. *Journal of Educational Psychology, 82*, 525-538. https://doi.org/10.1037/0022-0663.82.3.525

Gredler, M.S. (2001). *Learning and instruction: Theory into practice*. Upper Saddle River, N.J: Pearson/ Merrill Prentice Hall.

Hakan, K. & Munire, E. (2014). Academic motivation: Gender, domain and grade differences. *Procedia- Social Behavior in Science, 143*, 708-715. https://doi.org/10.1016/j.sbspro.2014.07.469

Hardinata, A., Djulia., Bukhari., & Siregar, A. (2021). Implementation of STEM and scientific literacy's aspects through lesson study on English for science course: Pre-service science teacher's initial

knowledge and plan stage. *Advances in Social Science, Education and Humanities Research, 591*, 887-890.

Hasanah, U. (2020). Key definitions of STEM education: Literature review. *Interdisciplinary Journal of Environmental and Science Education, 16*(3), e2217. https://doi.org/10.29333/ijese/8336

Hulleman, C.S., Barron, K.E., Kosovich, J.J., & Lazowski, R.A. (2016). Student motivation: Current theories, constructs, and interventions within an expectancy-value framework. *Springer International Publishing.* 241-278. https://doi.org/10.1007/978-3-319-28606-8_10

Kaldi, S., Filippatou, D., & Govaris, C. (2011). Project-based learning in primary schools: Effects on pupils' learning and attitudes. *Education 3-13, 39*(1), 35-47.

Kazu, I. Y., & Yalcin, K. (2021). The effect of stem education on academic performance: a meta-analysis study. *TOJET: The Turkish Online Journal of Educational Technology, 20*(4), 101-116.

Kelley, T.R., & Knowles, J.G. (2016). A conceptual framework for integrated STEM education. *Journal of STEM Education, 3*(11), 1-11. DOI:10.1186/s40594-016-0046-z

Koyuncuoglu, O. (2021). An investigation of academic motivation and career decidedness among university students. *International Journal of Research in Education and Science (IJRES), 7*(1), 125-143. https://doi.org/10.46328/ijres.1694

Lantz, H.B. (2009). Science, Technology, Engineering and Mathematics (STEM) education: What form? What function? CurrTech Integrations: Baltimore.

Lertcharoenrit, T. (2020). Enhancing collaborative problem-solving competencies by using STEM-based learning through the dietary plan lessons. *Journal of Education and Learning, 9(4), 102-117.*

Li, S. & Zheng, J. (2017). The effect of academic motivation on students' English learning achievement in the eSchoolbag-based learning. *Springer Open, 4*(3), 1-14. DOI: 10.1186/s40561-017-0042-x

MacFarlane, B. (2015). *STEM education for high-ability learners: Designing and implementing programming.* Prufrock Press.

Margot, K. C., & Rinn, A. N. (2016). Perfectionism in gifted adolescents: A replication and extension. *Journal of Advanced Academics, 27*(3), 190-209. http://doi.org/10.1177/1932202X16656452

Meester, J.D., Cock, M.D., Langie, G. & Dehaene, W. (2021). The process of designing integrated

STEM learning materials: Case study towards an evidence-based model. *European Journal of Stem Education, 6*(1), 10.

Morrison, J.S. (2006). TIES STEM education monograph series: *Attributes of STEM education.* Baltimore: MD: TIES

Murnawianto, S., Sarwanto, S., & Rahardjo, S.B. (2019). Sample learning design for heat transfer course: A STEM-based science learning. *Journal of physics: conference series, 1318*(1), DOI: 10.1088/1742-6596/1318/1/012076

National Policy of Education (2020). National Policy of Education. Available at https://www.mhrd.gov.in/sites/upload_files/mhrd/files/NEP_Final_English_0.pdf

National Research Council (2007). Rising above the gathering storm: Energizing and America for a brighter economic future, committee on science, engineering and public policy. Washington, DC: *National Academies Press.*

National Council for Teacher Education (2009). National Curriculum Framework for Teacher Education. NewDelhi. Available at https://ncte.gov.in/Website/PDF/NCFTE_2009.pdf.

National Council of Educational Research and Training. (2005). National Curriculum Framework. New Delhi. Available at http://www.ncert.nic.in/rightside/links/pdf/framework/english/nf2005.pdf.

Nurramadhani, A., Lathifah, S.S., & Permana, I. (2020). Students' generated questions quality by developing STEM-based E-Module in science learning. *Scientiae Edducatia: Jornal Pendidkan Sains 9*(2), 134-152. DOI: http://dx.doi.org/10.24235/sc.education.v9i2.7131.

Ozkan, F., & Kettler, T. (2022). Effects of STEM education on the academic success and social-emotional development of gifted students. *Journal of Gifted Education and Creativity, 9*(2), 143-163.

Pleasants, J., Clough, M.P., Olson, J.K., & Miller, G. (2019). Fundamental issues regarding the nature of technology. *Science & Education, 28*(3-5), 561-597. http://doi.org/10.1007/s11191-091-00056-y

Qamariyah, S.N., & et al, (2021). The effect of implementation of inquiry-based learning with socio-scientific issues on students' higher-order thinking skills. *Journal of Science Learning,* 210-218. http://doi.org/10.17509/jsl.v4i3.30863

Rintayati, P., Lukitasari, H., & Syawaludin, A. (2021). Development of two-tier multiple choice test to assess Indonesian elementary students' higher-order thinking skills. *International Journal of Instruction, 14*(1). 555-566. https://doi.org/10.29333/iji.2021.14133a

Sahay, K. (2016). Satisfactory Association, Education World. Retrieved from: http://www.educationworld.in/

Sahin, A., Ayar. M.C. & Adiguzel, T. (2014). STEM related after-school program activities, and associated outcomes on student learning. *Educational Sciences: Theory & Practice, 14*(1), 13-26. https://doi.org/10.12738/estp.2014.1.1876

Sanders, M. (2009). STEM, STEM education. STEMmania. *The Technology Teacher, 68*(4), 20-26.

Sari, N., Sumantri, M.S., & Bachtiar, I.G. (2018). The development of science teaching material based on STEM to increase science literacy ability of elementary school students. *International Journal of Advances in Scientific Research and Engineering, 4*(7), 161-169.

Sudarsana, J.K. (2016). Pemikiran tokoh Pendidikan dalam baku lifelong learning: Policies, practices, and programs. *Jurnal Penjaminam Mutu, 2*(2), 44. http://doi.org/10.25078/jpm.v2i.71

Sykili, A. (2019). Higher education in the digital age: The impact of digital connective technologies. *Journal of Educational Technology online learn, 2*(1), 1-15.

Self, J. (2020). *Teaching K-12 science and engineering during a crisis.* National Academy Press.

Stohlmann, M., Moore, T. J., & Roehrig, G.H. (2012). Consideration for teaching integrated STEM education. *Journal of Pre-College Engineering Education Research (J-PEER), 2*(1), 28-34.

Subiantoro, A.W. (2017). Biology learning based on socio-scientific issues (SSI) to train higher-order thinking skills. *Seminar Nasional Pendidikan Biologi.*

Sustiningsih., Utaminingsih, S., & Santoso. (2021). Development of science teaching materials based on STEM: A need analysis. *Journal of physics: Conference Series, 1823*(1). DOI: 10.1088/1742-6596/1823/1/012081

Tasdemir, F. (2022). Examination of effect of STEM education on academic achievement: A Meta-analysis study. *Education Quarterly Reviews, 5(*2), 282-298.

The Times of India. (2011). We need critical thinkers. The Times of India. Retrieved from: http://timesofindia.indiatimes.com/home/education/news/we-need-critical-

thinkers/articleshow/8835271.cms

The United States Department of Education. (2007). Report of Academic Competitiveness Council, Washington, DC: Author.

Tsupros, N., Kohler, R., & Hallinen, J. (2009). STEM education: A project to identify the missing components, *Intermediate Unit 1 and Carnegie Mellon*, Pennsylvania.

Ugras, M. (2018). The effect of STEM activities on STEM attitudes, scientific creativity and motivation beliefs of the students and their views on STEM education, *International Journal of Educational Sciences, 10*(5), 165-182.

Utama, C., Sajidan, Nurkamto, J., & Wiranto. (2020). The instrument development to measure higher-order thinking skills for pre-service biology teacher. *International Journal of Instruction, 13*(4), 833-848. http://doi.org/10.29333/iji.2020.13451a

Vallerand, R.J., et al. (1992). The academic motivation scale: A measure of intrinsic, extrinsic, and amotivation in education. *Education Psychology meaures, 52*(4), 1003-1017. https://doi.org/10.1177/0013164492052004025

Wahyu, Y., et al. (2020). The effect of science learning bases-STEM assisted by argumented reality towards scientific attitudes and science outcomes. *Journal of physics: conference series*, *1567*(4), DOI: 10.1088/1742-6596/1567/4/042015.

Wigfield, A., & Eccles, J.S. (2000). J.S. Expectany-value theory of achievement motivation. *Contemporary educational psychology 25*(1), 68-81. https://doi.org/10.1006/ceps.1999.1015

Wigfield, A., Tonks, S., & Klauda, S.L. (2009). In handbook of motivation at school. *Expectancy-value theory*, 55-75.

William, P. J. (2011). STEM education: proceed with caution. *Design and Technology Education: An International Journal*, *16*(1), 26-35.

Zohar, A., & Barzilai, S. (2015). Metacognition and teaching higher order thinking (HOT) in science education: Students' thinking, teacher' knowledge and instructional practices. In R.